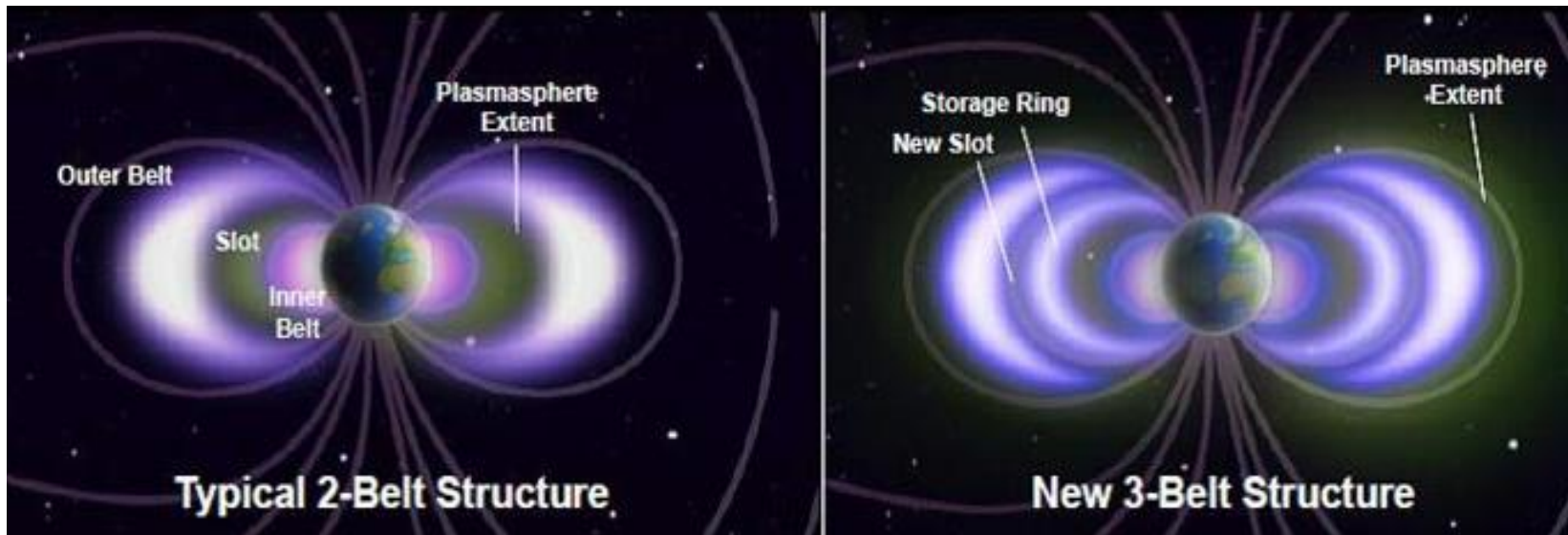


UN/ISWI Aug. 1, 2017

Transportation, acceleration and loss of electrons in the slot region responsible for the formation of new radiation belt during big magnetic storm.



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ABSTRACT

It was reported that relativistic electrons in the outer radiation belt have been transported into the slot region during big magnetic storms (Obara and Matsumoto, 2016 and references therein). Baker et al.(2013) further reported a new radiation belt has been made in some cases.

We have examined electron data in the radiation belt during magnetic storms paying a particular attention to the formation of new radiation belt. Issues, we like to clarify, will be followings: i.e. 1) electrons injected into the slot region will have additional (local) acceleration there ? 2) what is the cause of electron acceleration ? 3) how long electrons will feel acceleration ? and 4) what mechanism will be essential for the formation of new radiation belt ?

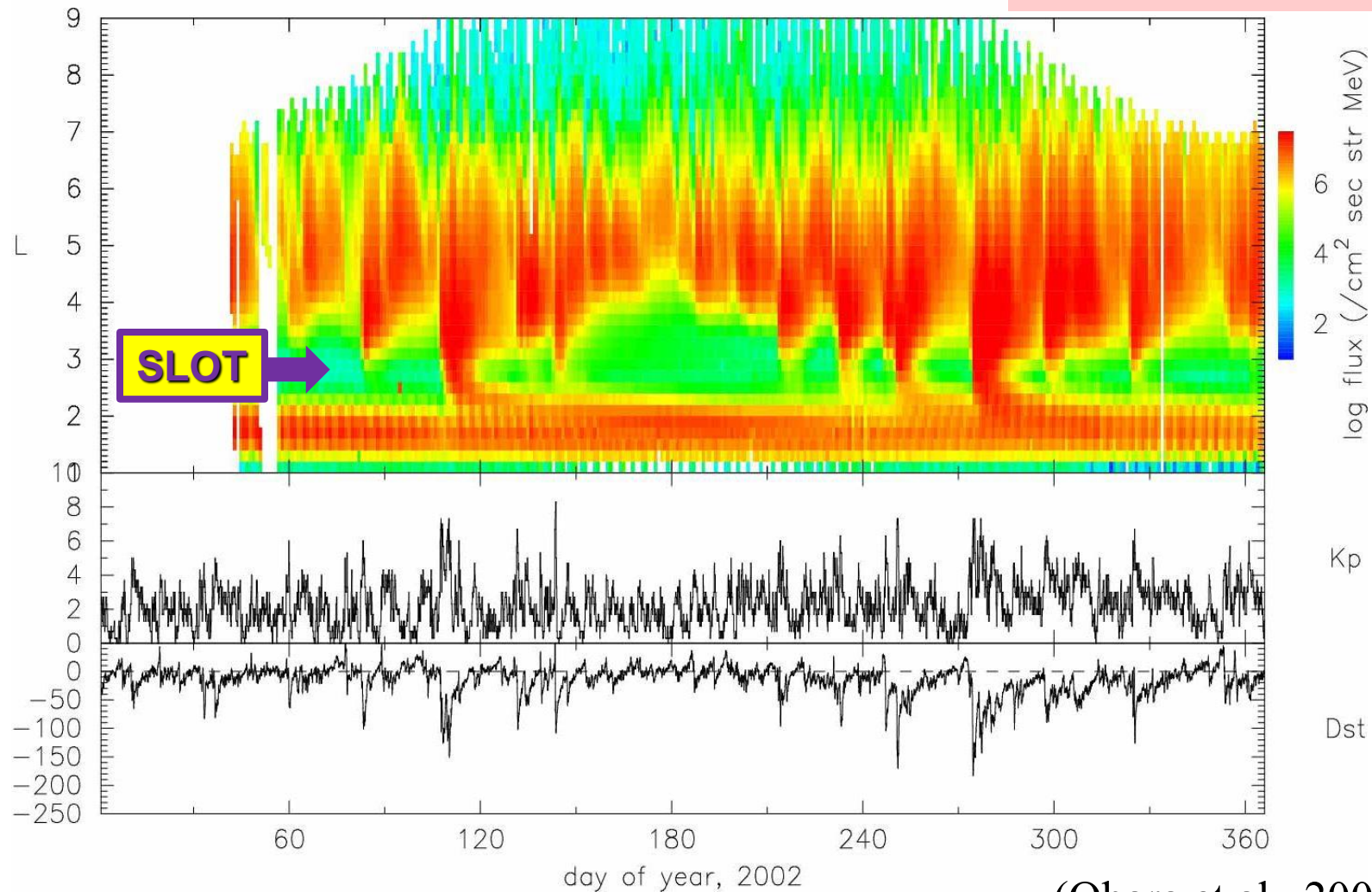
We have analyzed two events; one is March 24-th, 1991 event and the other is July 14-th, 2000 event. New radiation belt has been made at round $L \sim 3$ in both cases and it persisted for almost two weeks. In both cases, we have confirmed local acceleration. Intense very low frequency (VLF) plasma waves have been observed. We are considering additional acceleration has been made by these waves.

New point of our result will be the identification of local acceleration of electrons in very near Earth region; i.e. $L \sim 3$, and it also confirms the results by Baker et al.(2013).

The slot region is filled with high energy electrons. This phenomenon is seen during the major magnetic storms.

MDS-1 (TSUBASA)

0.4 MeV electrons

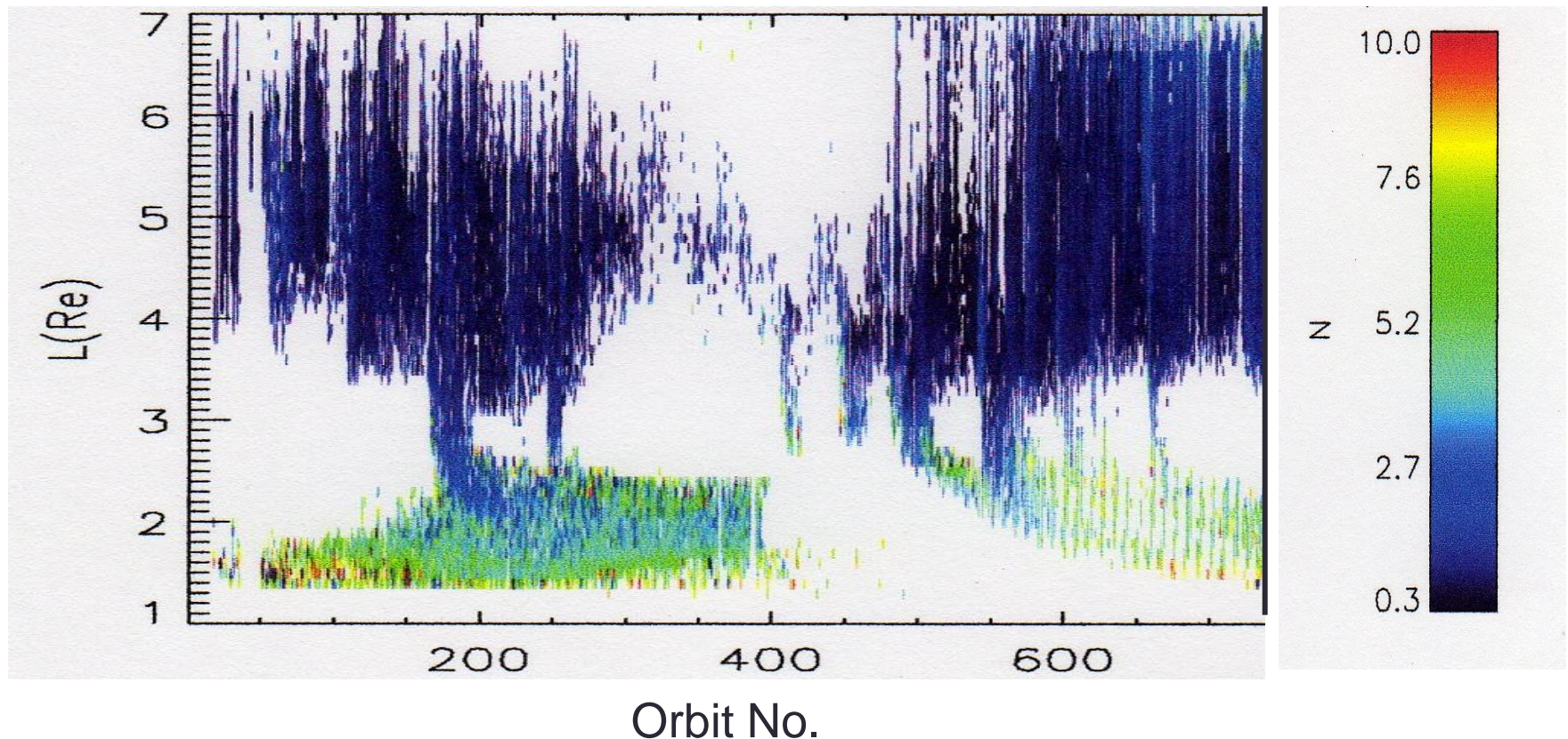


(Obara et al., 2004)

Obara and Matsumoto (2016) confirmed penetration of high energy electrons into the inner belt by means of fitting of the pitch angle distribution to of sinusoidal function; i.e. $\sin^N\theta$

MDS-1 (TSUBASA)

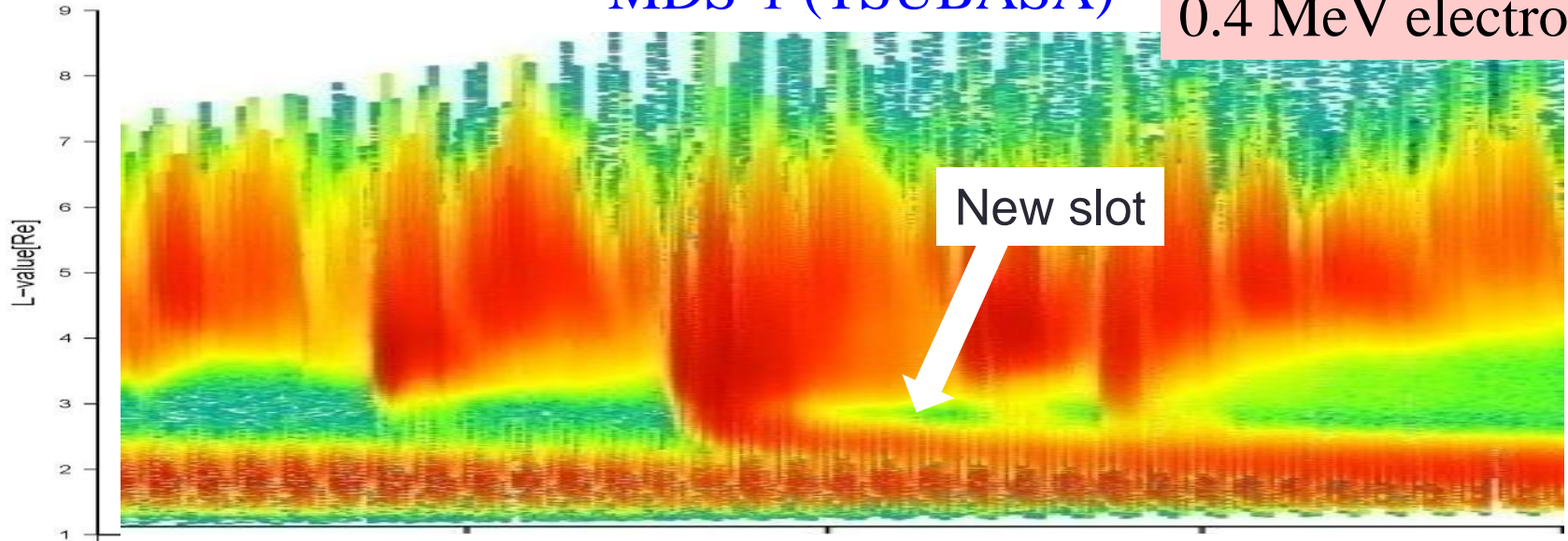
0.4 MeV electrons



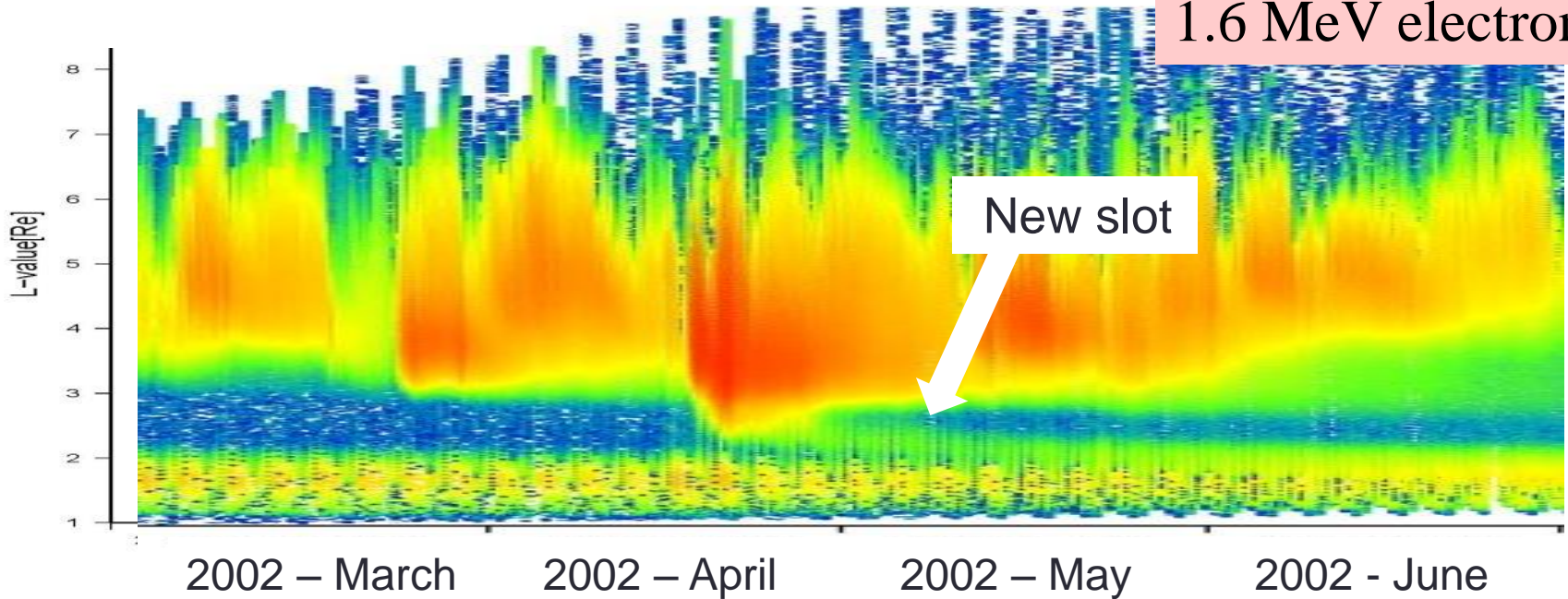
(Obara and Matsumoto, 2016)

MDS-1 (TSUBASA)

0.4 MeV electrons



1.6 MeV electrons



2002 - March

2002 - April

2002 - May

2002 - June

Purpose of this study

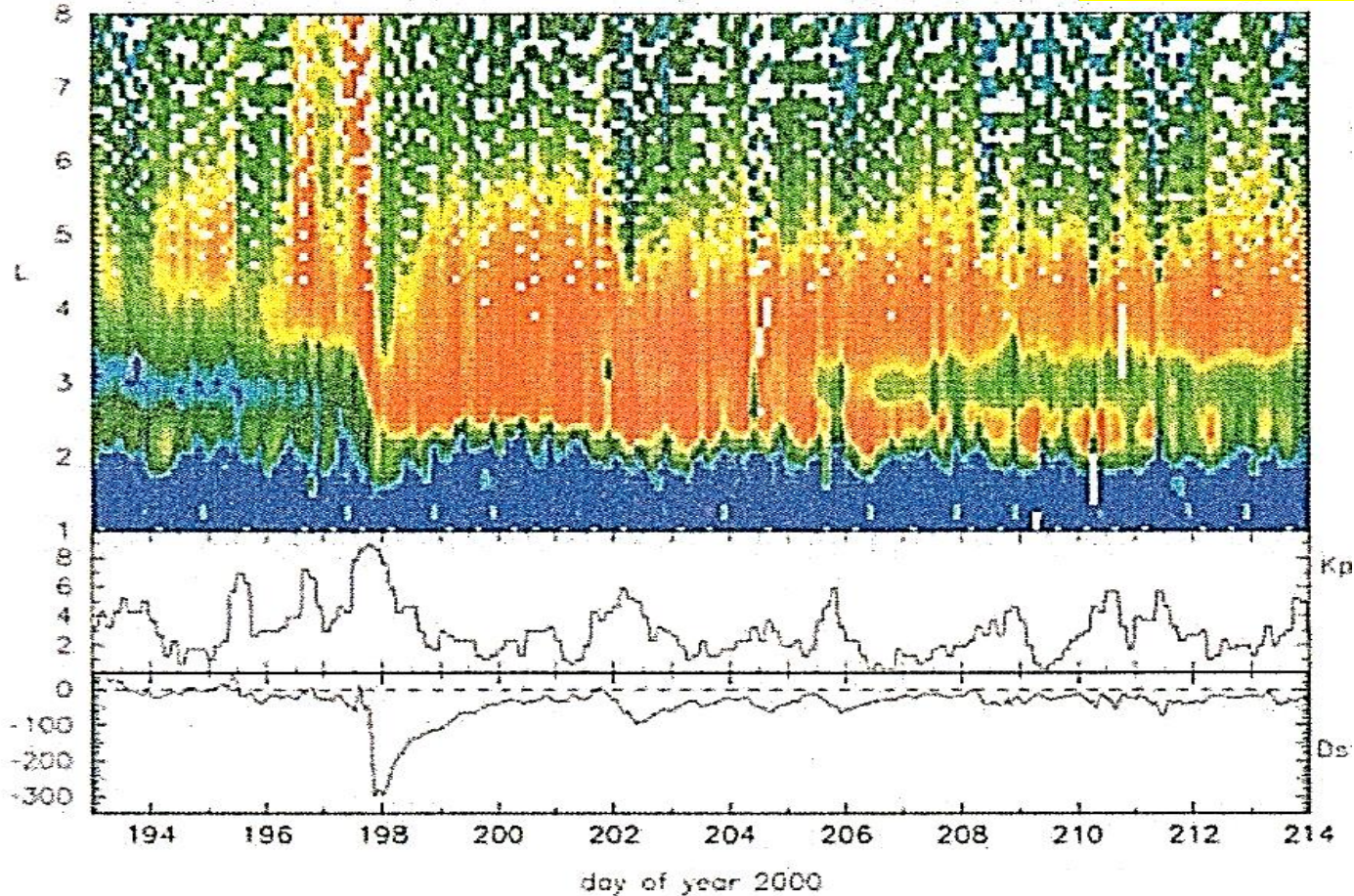
We will investigate electron injection into the slot region, which is thought to occur during the main phase of the magnetic storm by a large enhancement of the electric field by paying following attentions.

- 1) Electrons injected into the slot region will have additional (local) acceleration there ?
- 2) What is the cause of electron acceleration ?
- 3) How long electrons will feel acceleration ? and
- 4) What mechanism will be essential for the formation of new radiation belt ?

2000 July 14th Event (Total Day 193 – 214)

NOAA 15 MEPED

300keV - 1.1MeV

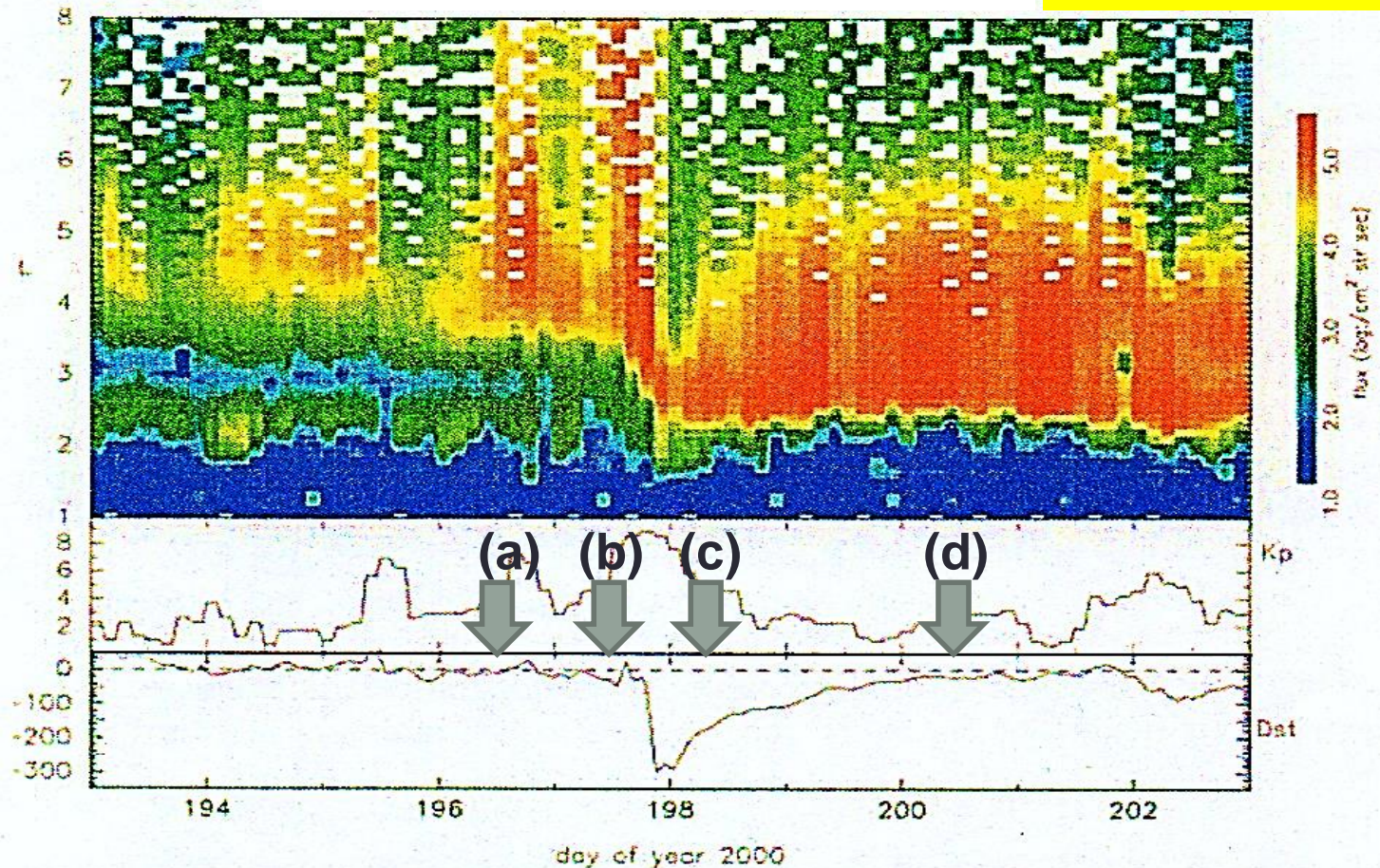


L-t diagram of high energy electrons for total day 193 to 214 in 2000. We see the formation of the slot region on the Day 205.

2000 July 14th Event (Total Day 193 – 202)

NOAA 15 MEPED

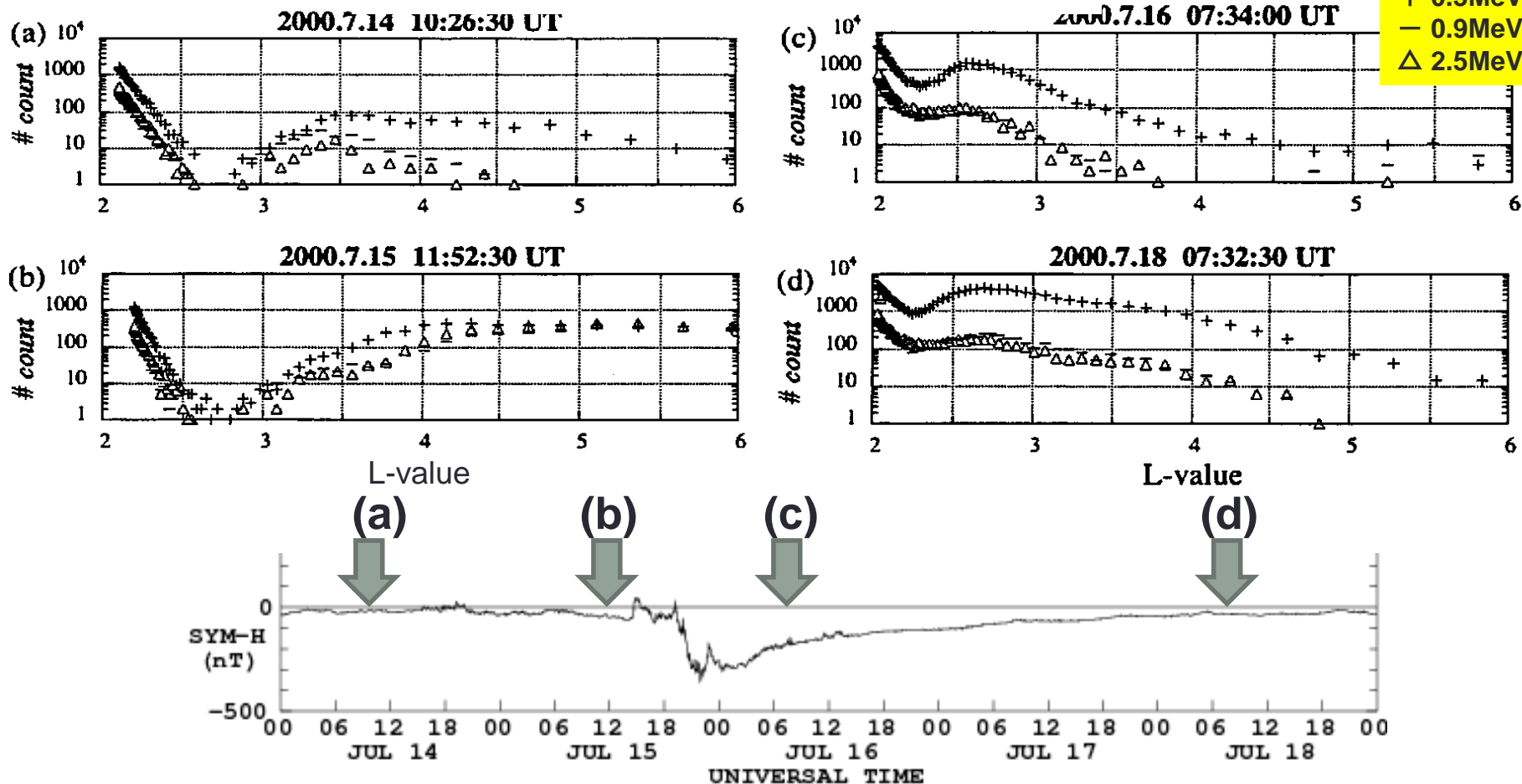
300keV - 1.1MeV



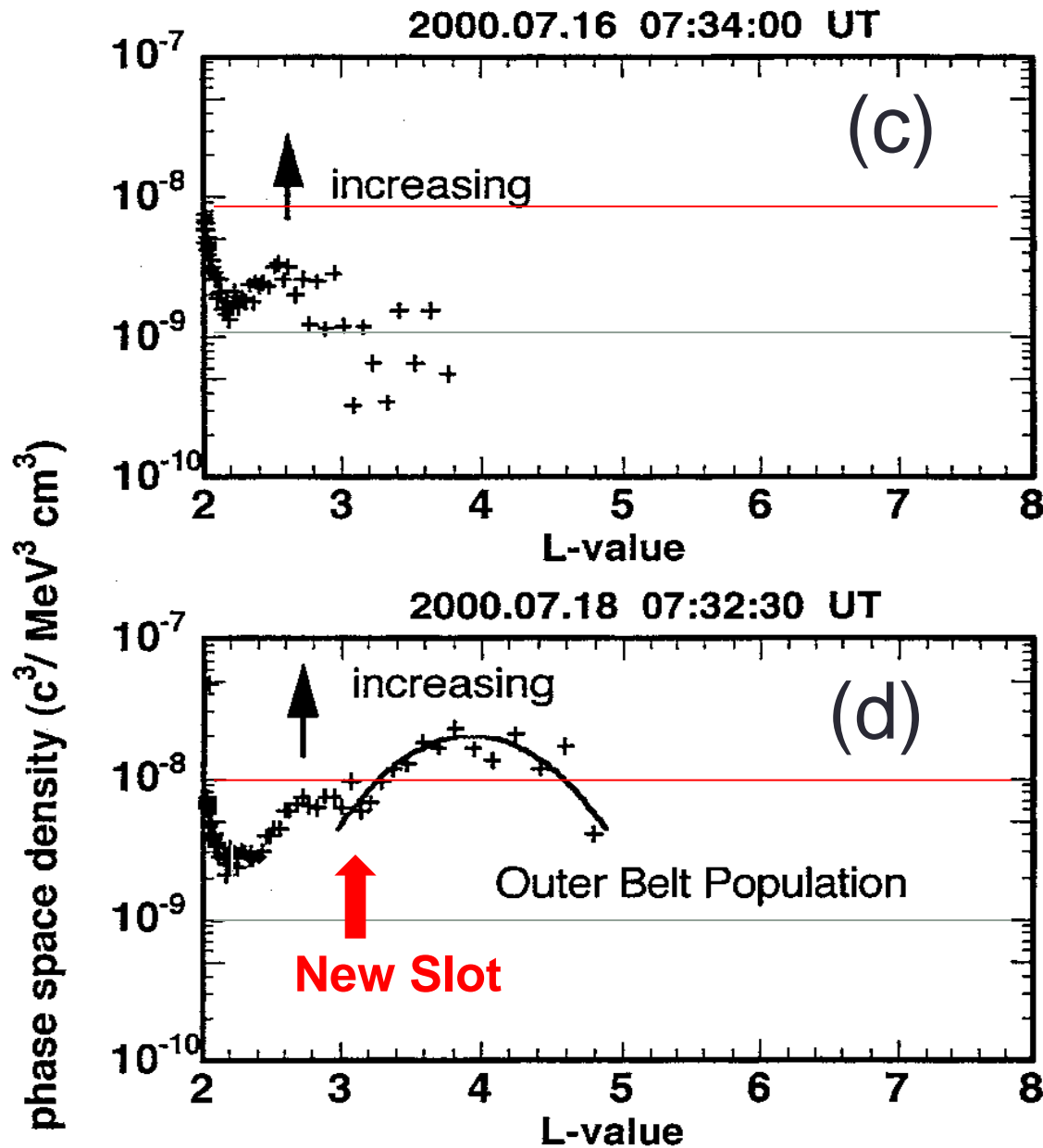
Outer belt electrons have been pushed into the inner radiation belt overt the slot region on the Day 197.

2000 July 14th Event (Total Day 196 – 200)

Akebono RDM



Time variation of high energy electron distribution for July 14 (Total Day 196) to July 18 (Total Day 200) in 2000 together with Dst index variation.



Outer belt electrons were pushed very much to $L=2.6$ during the main phase of the magnetic storm

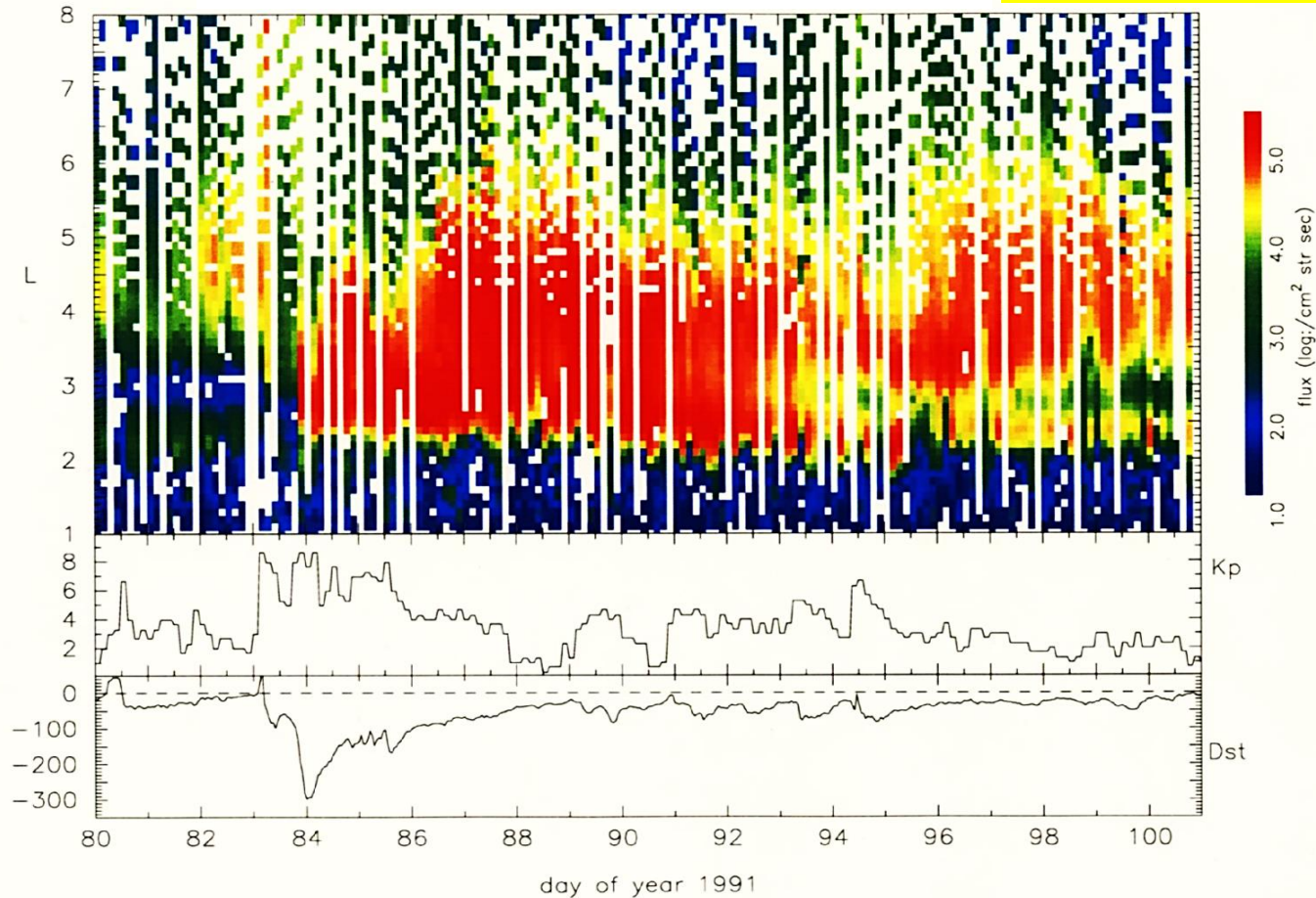
Two days later, outer belt was rebuilt. Increase of electron PSD was seen also in $L=2.6$.

We see **new slot** between above two regions.

1991 March 24th Event (Total Day 80 – 100)

NOAA 15 MEPED

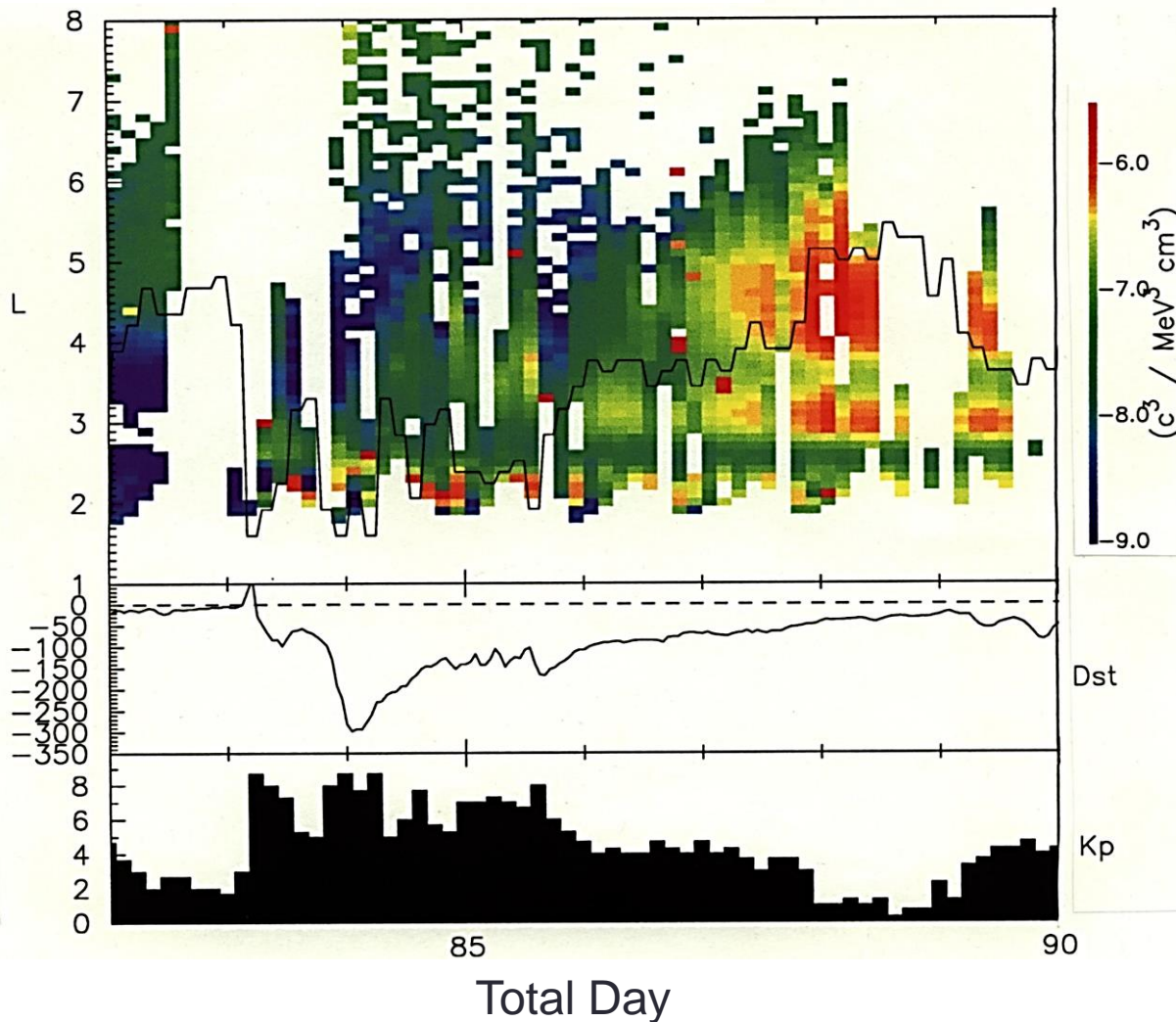
300keV - 1.1MeV



L-t diagram of high energy electrons for total day 80 to 100 in 1991. We see the formation of the slot region on the Day 93.

1991 March 24th Event (Total Day 82 – 89)

Akebono RDM $\mu = 1000 \text{ MeV/G}$

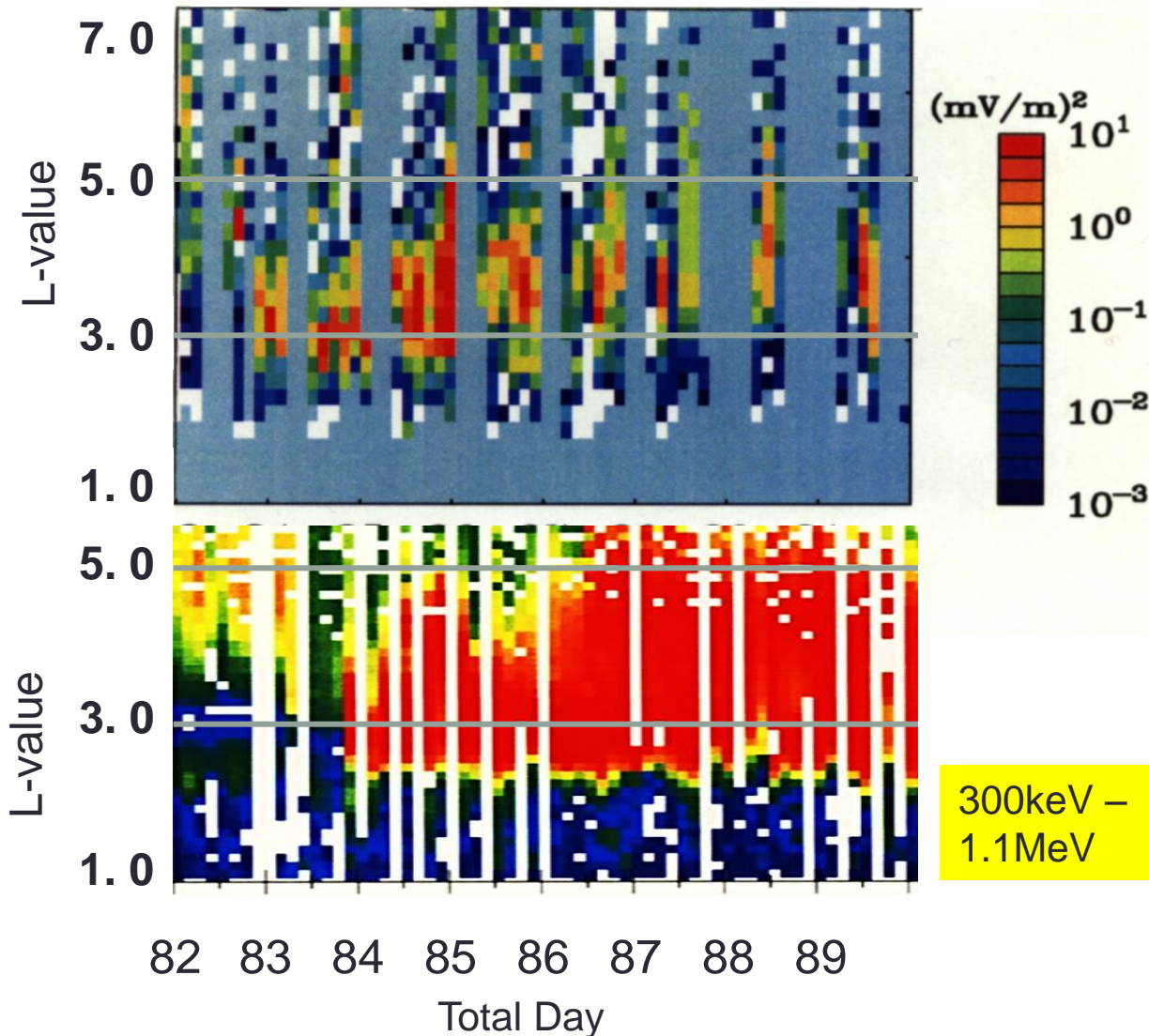


Increase of Phase Space Density was seen in the region of $L = 3 \sim 3.5$ on the Day 85.

In $L = 4 \sim 5$, PSD started to increase on the Day 87.

1991 March 24th Event (Total Day 82 – 89)

Akebono VLF

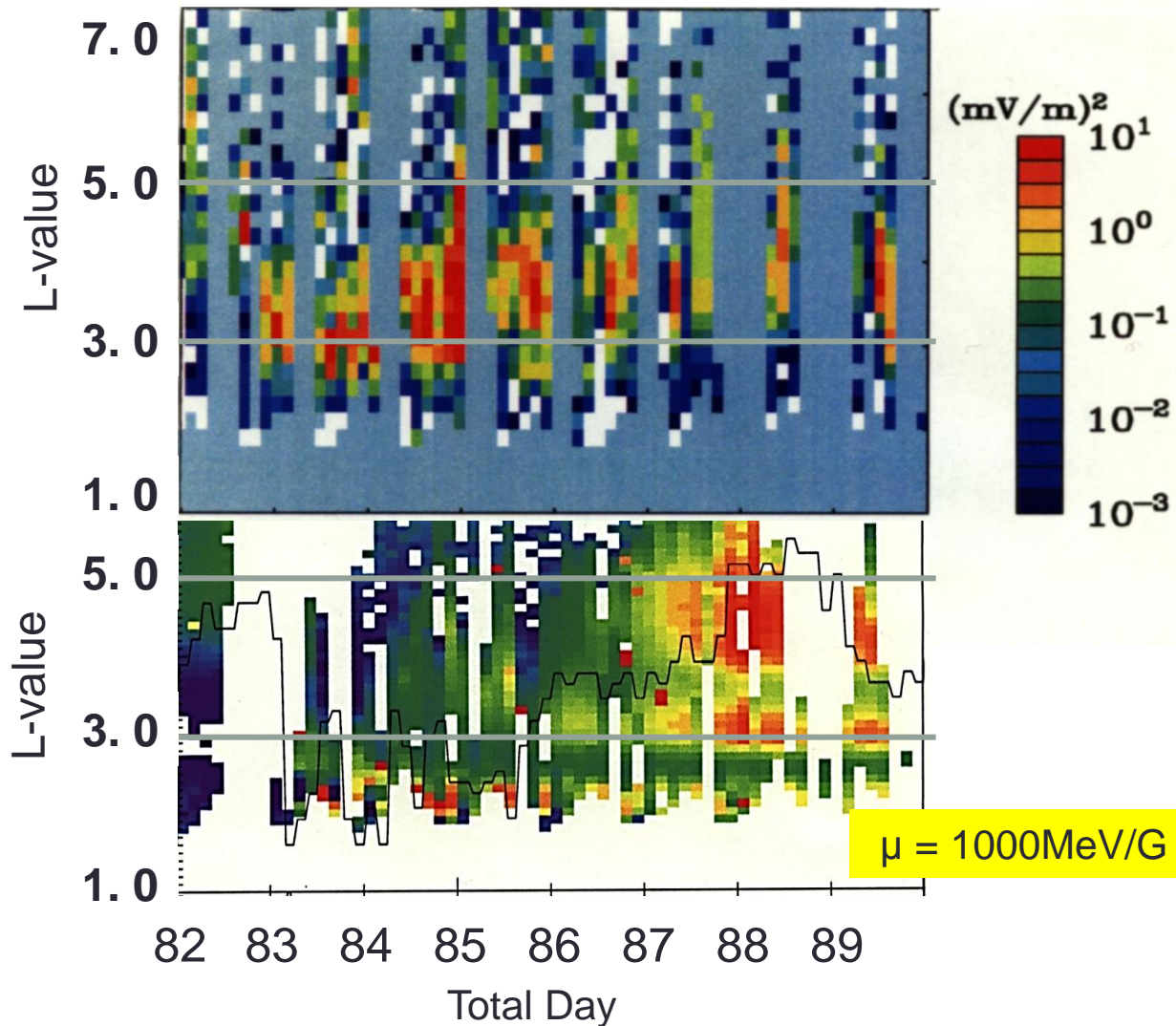


Electrons increased very much in the region of $3 < L < 6$ during the storm recovery phase.

During those periods, strong VLF wave emission were observed in the region of $3 < L < 5$.

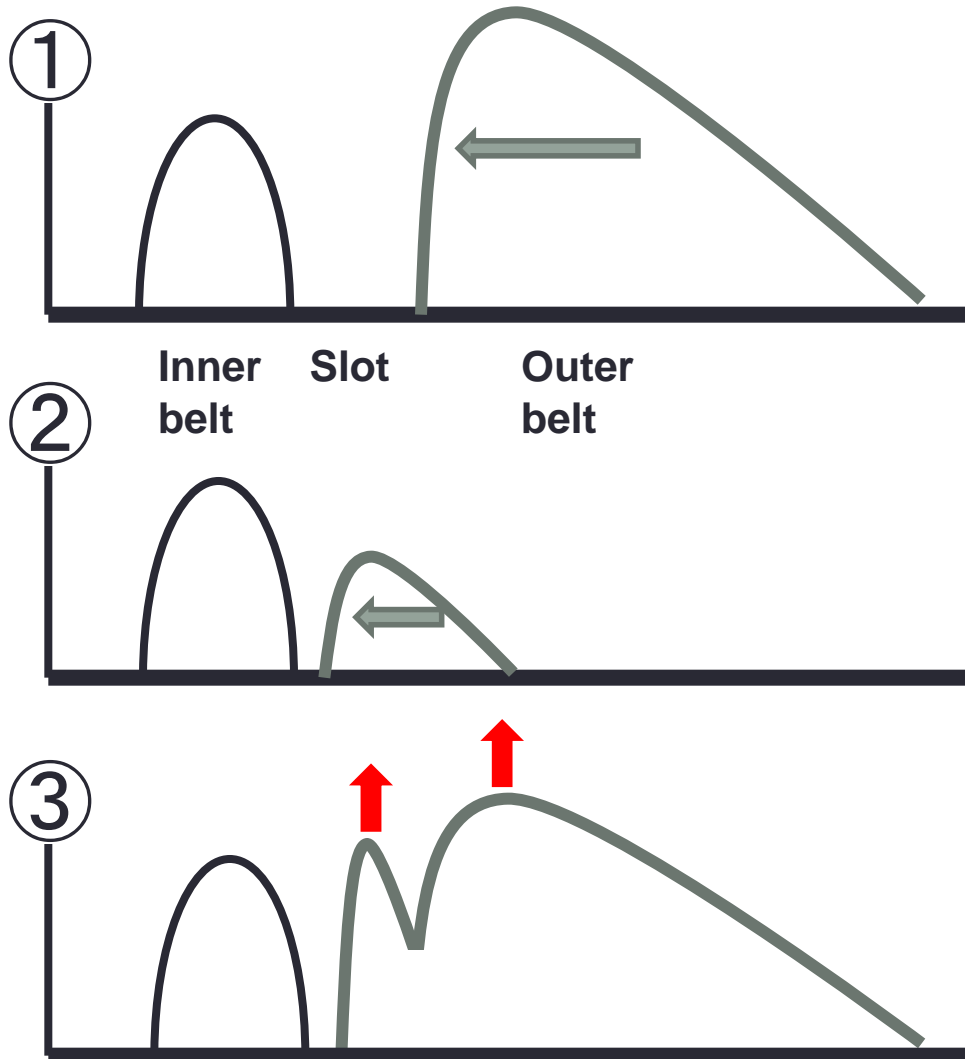
1991 March 24th Event (Total Day 82 – 89)

Akebono VLF



Phase Space Density started to increase on the Day 86. Very intense VLF emission has been seen from the Day 83, which is prior to the increase of PSD by three days.

Proposed Scenario



① Prior to the storm

- Clear outer belt, inner belt and slot region

② In the Main Phase

- Outer belt electrons were pushed toward the Earth

③ In the Recovery Phase

- Acceleration of remnant electrons, and strong loss process.

$L \sim 3 \rightarrow$ Acceleration

$L > 3 \rightarrow$ Loss

- New radiation belt was made in the center of outer belt; i.e. $L \sim 4$.

Summary

A new radiation belt was made as a storage of remnant electrons around $L \sim 3$.

Our results are consistent with Baker et al. (2013).

However, we found the additional acceleration of remnant storage for the first time

1. Electrons were accelerated locally by the VLF waves.
2. In the recovery phase of the magnetic storm, loss is evident in the region of $L > 3$. Hence, remnant of electrons has been seen only in the region of $L < 3$.
3. New outer belt has been made in the region of $L \sim 4$.

References

Baker et al., A Long-Lived Relativistic Electron Storage Ring Embedded in Earth's Outer Van Allen Belt, *Science*, Vol.340, 186-190, 2013

Obara, T. and H. Matsumoto, Large enhancement of highly energetic electrons in the outer radiation belt and its transport into the inner radiation belt inferred from MDS-1 satellite observations, *Sun and Geosphere*, No.11, Vol.1, 61-64, 2016

Obara, T., H. Matsumoto, T. Goka, Coupling of energetic electrons in the inner magnetosphere to space weather phenomena, *Multiscale Coupling of Sun-Earth Processes* ed. by Lui, T, and Y. Kamide 135-144, 2004